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23 JUN 2003

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1. Your reference

AA 1659 GB

2. Patent application number *(The Patent Office will fill in)*

0314463.1

23JUN03 E816777-1 001091
P01/7700 0.00-0314463.1

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

JOHNSON MATTHEY PUBLIC LIMITED COMPANY
2-4 COCKSPUR STREET
TRAFALGAR SQUARE
LONDON SW1 5BQ

Patents ADP number *(if you know it)*

53626800 9

If the applicant is a corporate body, give the country/state of its incorporation

GB.

4. Title of the invention

METHOD OF CALIBRATING REDUCTANT INJECTION IN A SCR SYSTEM

5. Name of your agent *(if you have one)*

ANDREW DOMINIC NUNN

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

JOHNSON MATTHEY TECHNOLOGY CENTRE
BLOUNT'S COURT
SONNING COMMON
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Patents ADP number *(if you know it)*

3991411001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

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a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
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See note (d))

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Claim(s)	7
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
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Any other documents *(please specify)*	1 CONTINUATION OF BOX 3.

11. I/We request the grant of a patent on the basis of this application.

Signature Andrew Nunn ANDREW NUNN Date 23/6/03.

12. Name and daytime telephone number of person to contact in the United Kingdom FRANCES STRANGE 0118 924 2125

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"METHOD OF CALIBRATING REDUCTANT INJECTION IN A SCR SYSTEM"

Continuation of Box 3.

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DUPLICATE

METHOD OF CALIBRATING REDUCTANT INJECTION IN A SCR SYSTEM

The present invention relates to a method and apparatus for mapping injection of a reductant, such as a NO_x specific reactant, onto NO_x in exhaust gas from a lean-burn internal combustion engine. More particularly, it relates to such a method and apparatus wherein the engine comprises an exhaust system comprising a selective catalytic reduction (SCR) catalyst for reducing NO_x to N_2 with the reductant, thereby to meet a desired emission standard for NO_x.

By "NO_x" herein, we mean "nitrogen oxides" including "nitrogen monoxide (NO)" and "nitrogen dioxide (NO_2)". Whilst we refer herein to "NO_x sensors", by this we mean also sensors that measure total NO_x, sensors that can selectively detect the amount of NO in the NO_x present and also sensors that can selectively detect the amount of NO_2 in the NO_x present.

It is has been suggested to use neural networks (or fuzzy logic) in process design and process modelling in exhaust systems for internal combustion engines (see e.g. SAE 2000-01-0212 "Three-way Catalytic Converter Modelling: Neural Networks and Genetic Algorithm for the Reaction Kinetics Submodel", L. Glielmo et al.) In computing terms, neural networks have a number of advantages over theoretical modelling or modelling based on experimentally measured input-output data to build an empirical model. They can learn from experience; generalise from examples; and abstract essential information from "noisy" data. However, they can only provide good results for certain types of problem, and then only when a great deal of care is taken over neural network design and input data pre-processing data.

Reductant injection into exhaust systems of lean-burn internal combustion engines for the purpose of reducing NO_x to N_2 over a suitable catalyst is known. Such an approach is generally termed "selective catalytic reduction" or SCR. Where the reductant is a hydrocarbon, such as the fuel used to power the engine, the technology is generally called hydrocarbon SCR, or lean NO_x catalysis and the catalysts are called SCR catalysts, or more specifically, lean NO_x catalysts or denox catalysts. Typical catalysts are copper exchanged zeolite e.g. ZSM5 or platinum on alumina. NO_x in the exhaust gas competes with other oxidising agents such as oxygen (O_2) for the hydrocarbon, and NO_x conversion in a drive cycle is of the order of about 40%. Accordingly, this form of SCR is sometimes referred to as non-selective SCR or NSCR.

An alternative form of SCR uses NO_x specific reactants as reductants and reduction is more selective than lean NO_x catalysis. Typical catalysts comprise platinum, supported vanadium (V_2O_5) e.g. on titania (TiO_2) or zeolites e.g. mordenite. For reasons that will become obvious, this form of SCR is often referred to as ammonia (NH_3)-SCR.

By "NO_x specific reactant" herein, we mean a reducing agent that, in most conditions, preferentially reduces NO_x over other components of a gaseous mixture. Examples of NO_x-specific reactants include nitrogenous compounds such as nitrogen hydrides, e.g. ammonia (NH_3) or hydrazine, or an NH_3 precursor.

By "NH_3 precursor" we mean one or more compounds from which NH_3 can be derived, e.g. by hydrolysis. These include urea ($CO(NH_2)_2$) as an aqueous solution or as a solid or ammonium carbamate (NH_2COONH_4). If the urea is used as an aqueous solution, a eutectic mixture, e.g. a 32.5% NH_3 (aq), is preferred. Additives can be included in the aqueous solutions to reduce the crystallisation temperature.

Urea hydrolyses at temperatures above 160°C according to equation (1) to liberate NH_3 itself. It also thermally decomposes at this temperature and above according to equations (2) and (3) resulting in reduction of NO_x.

$$CO(NH_2)_2 + H_2O \rightarrow 2NH_3 + CO_2 \qquad (1)$$

$$CO(NH_2)_2 \rightarrow .NH_2 + CO \qquad (2)$$

$$.NH_2 + NO \rightarrow N_2 + H_2O \qquad (3)$$

The NH_3 can be in anhydrous form or as an aqueous solution, for example.

The application of NH_3 SCR technology to treat NO_x emissions from IC engines, particularly lean-burn IC engines, is well known. Several chemical reactions occur in the NH_3 SCR system, all of which represent desirable reactions which reduce NO_x to elemental nitrogen. The dominant reaction mechanism is represented in equation (4).

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O \qquad (4)$$

Competing, non-selective reactions with oxygen can produce secondary emissions or may unproductively consume NH_3. One such non-selective reaction is the complete oxidation of NH_3, represented in equation (5).

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O \qquad (5)$$

Presently, urea is the preferred source of NH_3 for mobile applications because it is less toxic than NH_3, it is easy to transport and handle, is inexpensive and commonly available.

Early methods of using urea as a source of NH_3 in exhaust systems involved injecting urea directly into the exhaust gas, optionally over an in-line hydrolysis catalyst (see EP-A-0487886 (incorporated herein by reference)). However, not all urea is hydrolysed in such arrangements, particularly at lower temperatures.

Incomplete hydrolysis of urea can lead to increased PM emissions on tests for meeting the relevant emission test cycle because partially hydrolysed urea solids or droplets will be trapped by the filter paper used in the legislative test for PM and counted as PM mass. Furthermore, the release of certain products of incomplete urea hydrolysis, such as cyanuric acid, is environmentally undesirable. Another method is to use a pre-injection hydrolysis reactor (see US-A-5,968,464 (incorporated herein by reference)) held at a temperature above that at which urea hydrolyses.

It will be appreciated that at lower temperatures, below about 100-200°C, NH_3 can also react with NO_2 to produce explosive ammonium nitrate (NH_4NO_3) according to equation (6):

$$2NH_3 + 2NO_2 + H_2O \rightarrow NH_4NO_3 + NH_4NO_2 \qquad (6)$$

For the avoidance of doubt, in so far as the invention uses NH_3-SCR, the present invention does not embrace reactions such as reaction (6) or the promotion of conditions which bring them about. For example, the reaction can be avoided by ensuring that the temperature does not fall below about 200°C or by supplying into a gas stream less than the precise amount of NH_3 necessary for the stoichiometric reaction with NO_x (1 to 1 mole ratio). For cold start applications, measures to prevent water from contacting the catalyst can be adopted. These can include disposing a water trap, e.g. a zeolite, upstream of the catalyst to reduce the amount of

water vapour contacting the catalyst until it is heated sufficiently. A water trap can also be positioned downstream of the catalyst, to prevent atmospheric humid air from travelling up the exhaust pipe. An electric heater can also be employed to drive off moisture from the catalyst pre-cold start. Such arrangements are described in our EP 0747581, (incorporated herein by reference).

One problem in adopting SCR technology is controlling the addition of the reductant: if too little reductant is added, NO_x conversion may be insufficient to meet emission standards. On the other hand, if too much reductant it may be exhausted to atmosphere - hydrocarbon is a legislated pollutant and NH_3 is a biological poison and is detected as NO_x in tests for meeting such standards.

In order to avoid such problems, extensive bench testing and modelling is carried out to establish engine maps and look-up tables to match e.g. urea injection to engine-out NO_x. However, such testing is time consuming and extremely expensive.

We have now devised a method of establishing such maps and look-up tables which overcomes problems associated with the prior art and is particularly applicable to the retrofit market. In retrofit applications, the invention is based on the idea of fitting NO_x sensors to the exhaust system of the vehicle, preferably downstream of the SCR catalyst, to input measurements on NO_x detected in the system to a suitable processor means, e.g. the vehicle's electronic control unit (ECU). The ECU may be the engine control unit or separate therefrom but communicable with the engine control unit. The ECU is used to correlate NO_x values with at least one additional physical variable indicative of the condition of the engine. The vehicle is then driven normally for a period of, say, a few weeks, during which time the processor processes and collects the correlated data. Finally, the NO_x sensors can be removed and the vehicle, now comprising a processor that actuates reductant injection in response to detected input from the at least one additional physical variable indicative of the condition of the engine, can be used normally.

Accordingly, the expense and time normally required to develop maps for reductant injection can be avoided. Furthermore, certain embodiments of the invention comprise empirical determination of the amount of reductant required to treat NO_x, the method is more likely to reduce NO_x emissions than data generated from models or bench testing. A further advantage

springs from the fact that, since NO_x sensors can be removed following mapping, the problems of NO_x sensor cost and durability is reduced or avoided. Moreover, it is known from e.g. EP 1054722 that NO_x conversion over certain SCR catalysts can be improved if the $NO:NO_2$ ratio is adjusted to a particular range of values. Accordingly, by positioning a NO_x sensor upstream of the SCR catalyst, it may also be possible to adjust $NO:NO_2$ ratio e.g. at selected temperatures for optimal NO_x conversion.

The methods of the invention can use established techniques such as neural network technology. Adequate safeguards such as "mop-up" oxidation catalysts to prevent excessive emission of hydrocarbon or NH_3 to atmosphere during collection of such generalisation data or testing of training algorithm can be provided as necessary.

Therefore, according to a first aspect, the invention provides a method of mapping reductant injection onto NO_x in exhaust gas in a vehicle comprising a lean-burn internal combustion engine and an exhaust system comprising a selective catalytic reduction (SCR) catalyst for reducing NO_x to N_2 with the reductant, thereby to meet a desired emission standard for NO_x, which method comprising measuring NO_x in the exhaust gas as the vehicle is driven and correlating a measured NO_x value with a value of at least one measurable parameter indicative of a condition of the engine.

The method of the present invention is particularly applicable to the retrofit market, e.g. so that vehicles can be meet certified standards to enter areas, such as parts of cities, wherein access is denied to vehicles not meeting proscribed emissions standards. Therefore, according to a second aspect, the invention provides a method of retrofitting a vehicle comprising a lean-burn internal combustion engine with a system for meeting a desired emission standard for NO_x, which system comprising means for injecting a reductant into exhaust gas and a selective catalytic reduction (SCR) catalyst for reducing NO_x to N_2 with the reductant, which method comprising fitting the existing exhaust system with at least one NO_x sensor for measuring NO_x in the exhaust gas as the vehicle is driven and correlating a measured NO_x value with a value of at least one measurable parameter indicative of a condition of the engine

In one embodiment according to the first or second aspect of the invention, the method comprises the step of using the correlated value to determine the amount of reductant required to

reduce the measured value of NO_x by a desired amount for the measured value of the at least one measurable parameter.

In its broadest aspect, the invention enables collection of correlated data and "off-line", e.g. using bench engine analysis, to arrive at amounts of reductant to be injected into the system to reduce NO_x by a desired amount. However, in a preferred embodiment, the determination of reductant amounts is performed "on-line" as the vehicle is driven providing empirically measurable "finessing" of reductant addition through measurement of NO_x and/or reductant e.g. downstream of the SCR catalyst to arrive at adjusted reductant amount values.

Therefore, in particular embodiments of the first and second aspect, the method comprises the step of injecting the amount of reductant so-determined as the vehicle is driven, measuring exhaust gas downstream of the SCR catalyst for the presence of reductant and/or NO_x and adjusting the so-determined amount of reductant to reduce NO_x emissions and/or prevent reductant slip as necessary. Such a "learned" response is an aspect of neural network or "fuzzy logic" technology.

In an embodiment according to either the first or second aspect of the invention, as appropriate, the or each correlation step, the or each step of determining the amount of reductant and/or the step of adjusting the so-determined amount of reductant to reduce NO_x emissions and/or prevent reductant slip is performed by a processor. Such processor can be part of an electronic control unit (ECU).

According to a further embodiment of the first and second aspects of the invention, the correlated values, the amounts of reductant determined and/or the adjusted reductant amounts are stored as look-up tables or maps, for example, in the ECU.

Ordinarily, modern vehicle ECU's for controlling engine function do not have the processor and/or storage capability necessary for applying the methods according to the first and second aspects of the invention. It is envisaged, therefore, that in the first or second aspect the vehicle ECU is removed and replaced for the period of mapping with an ECU with the necessary processor and/or storage capacity. Following the mapping procedure, the original ECU can be re-programmed with the appropriate look up tables or maps and algorithms or a fresh ECU so-programmed can be inserted. Of course, if the original ECU of the vehicle has the required

processor and/or storage capacity, no such ECU switching/re-programming is necessary. Alternatively, the capacity of the original ECU can be supplemented by additional processor/storage capacity for the period of the analysis.

In one particular aspect according to the first aspect of the invention, NO_x is detected using at least one NO_x sensor positioned either upstream and/or downstream of the SCR catalyst. However, since NO_x sensors are expensive and have limited durability, the first and second aspects of the invention can comprise the steps of removing the at least one NO_x sensor after the amount of reductant required to reduce the measured value of NO_x as indicated by the measured value of the at least one measurable parameter has been determined or the determined value has been adjusted. Thereafter, it is possible to treat the NO_x by detecting the at least one measurable parameter indicative of a condition of the engine and injecting an amount of reductant appropriate to the value detected.

The at least one measurable parameter can be any parameter indicative of the condition of the engine. It is envisaged that one or more of the following may be used: exhaust gas temperature; mass flow of exhaust gas in the system; manifold vacuum; ignition timing; engine speed; throttle position (accelerator position); the lambda value of the exhaust gas; the quantity of fuel injected in the engine; the position of the exhaust gas recirculation (EGR) valve and thereby the amount of EGR; boost pressure; and engine coolant temperature. Sensors for measuring all these parameters are known to the skilled person.

The reductant can be a hydrocarbon and the SCR catalyst can be a lean NO_x catalyst e.g. any of those mentioned above, or the reductant can be a NO_x specific reactant, such as a nitrogen hydride, e.g. ammonia (NH_3) or hydrazine, or an NH_3 precursor and the SCR catalyst can be a platinum-based catalyst, a supported vanadium such as V_2O_5/TiO_2 or a zeolite, such as mordenite. The NH_3 precursor can be urea ($CO(NH_2)_2$) or ammonium carbamate (NH_2COONH_4), for example.

According to a third aspect, the invention comprises an apparatus for mapping reductant injection onto NO_x in exhaust gas in a vehicle comprising a lean-burn internal combustion engine and an exhaust system comprising a selective catalytic reduction (SCR) catalyst for reducing NO_x to N_2 with the reductant, thereby to meet a desired emission standard for NO_x, which apparatus comprising at least one NO_x sensor for measuring NO_x in the exhaust gas,

means for measuring at least one measurable parameter indicative of a condition of the engine and means for correlating a measured NO_x value with the value for the at least one measurable parameter.

The at least one NO_x sensor is preferably downstream of the SCR catalyst. Where the system also includes a reductant sensor, this also is preferably positioned downstream of the SCR catalyst. The system also can comprise a source of reductant, e.g. a hydrocarbon fuel such as diesel or a NO_x specific reactant as defined herein.

According to a fourth aspect, the invention provides a vehicle comprising an apparatus according to the invention. Such vehicle can be powered by any suitable fuel such as gasoline or preferably diesel. Alternative fuel such as liquid petroleum gas, natural gas and methanol may also be used.

Where the vehicle comprises a diesel engine, it can be a heavy-duty diesel engine or light duty diesel engine according to the relevant legislation.

CLAIMS:

1. A method of mapping reductant injection onto NO_x in exhaust gas in a vehicle comprising a lean-burn internal combustion engine and an exhaust system comprising a selective catalytic reduction (SCR) catalyst for reducing NO_x to N_2 with the reductant, thereby to meet a desired emission standard for NO_x, which method comprising measuring NO_x in the exhaust gas as the vehicle is driven and correlating a measured NO_x value with a value of at least one measurable parameter indicative of a condition of the engine.

2. A method according to claim 1, comprising the step of using the correlated value to determine the amount of reductant required to reduce the measured value of NO_x to/by a desired amount for the measured value of the at least one measurable parameter.

3. A method according to claim 2, comprising the step of injecting the amount of reductant so-determined as the vehicle is driven, measuring exhaust gas downstream of the SCR catalyst for the presence of reductant and/or NO_x and adjusting the so-determined amount of reductant to reduce NO_x emissions and/or prevent reductant slip as necessary.

4. A method of retrofitting a vehicle comprising a lean-burn internal combustion engine with a system for meeting a desired emission standard for NO_x, which system comprising means for injecting a reductant into exhaust gas and a selective catalytic reduction (SCR) catalyst for reducing NO_x to N_2 with the reductant, which method comprising fitting the existing exhaust system with at least one NO_x sensor for measuring NO_x in the exhaust gas as the vehicle is driven and correlating a measured NO_x value with a value of at least one measurable parameter indicative of a condition of the engine

5. A method according to claim 4, comprising the step of using the correlated value to determine the amount of reductant required to reduce the measured value of NO_x by a desired amount for the measured value of the at least one measurable parameter.

6. A method according to claim 5, comprising the step of injecting the amount of reductant so-determined as the vehicle is driven, measuring exhaust gas downstream of the SCR catalyst for the presence of reductant and/or NO_x and adjusting the so-determined amount of reductant to reduce NO_x emissions and/or prevent reductant slip as necessary.

7. A method according to any of claims 1 to 6, wherein the or each correlation step and/or the or each step of determining the amount of reductant is performed by a processor.

8. A method according to claim 3 or 6, wherein the step of adjusting the so-determined amount of reductant to reduce NO_x emissions and/or prevent reductant slip as necessary is performed by a processor.

9. A method according to claim 7 or 8, wherein the processor is part of an electronic control unit (ECU).

10. A method according to any preceding claim, wherein the correlated values, the amounts of reductant determined and/or the adjusted reductant amounts are stored as look-up tables or maps.

11. A method according to claim 10, wherein the correlated values and/or amounts are stored on an ECU.

12. A method according to claim 8 or 10, wherein the ECU used to perform the or each correlation step, to determine reductant amounts and/or to determine adjusted reductant amounts is replaced with an ECU programmed with look-up tables or maps comprising the determined or adjusted amount of reductant required for any detected value of the at least one measurable parameter.

13. A method according to claim 1, 2, 3 or any of claims 7 to 12 appendant to claims 1, 2 or 3, wherein at least one NO_x sensor is used to measure the NO_x.

14. A method according to claim 4, 5 or 6, any of claims 7 to 12 when appendant to claim 4, 5 or 6, and claim 13, wherein the at least one NO_x sensor is removed after the amount of reductant required to reduce the measured value of NO_x for the measured value of the at least one measurable parameter has been determined or the determined value has been adjusted.

15. A method according to any preceding claim, wherein the at least one measurable parameter is exhaust gas temperature.

16. A method according to any of claims 1 to 14, wherein the at least one measurable parameter is mass flow of exhaust gas in the system.

17. A method according to any of claims 1 to 14, wherein the at least one measurable parameter is manifold vacuum.

18. A method according to any of claims 1 to 14, wherein the at least one measurable parameter is ignition timing.

19. A method according to any of claims 1 to 14, wherein the at least one measurable parameter is engine speed.

20. A method according to any of claims 1 to 14, wherein the at least one measurable parameter is throttle position.

21. A method according to any of claims 1 to 14, wherein the at least one measurable parameter is the lambda value of the exhaust gas.

22. A method according to any of claims 1 to 14, wherein the at least one measurable parameter is the quantity of fuel injected in the engine.

23. A method according to any of claims 1 to 14, wherein the at least one measurable parameter is the position of the exhaust gas recirculation (EGR) valve and thereby the amount of EGR.

24. A method according to any of claims 1 to 14, wherein the at least one measurable parameter is boost pressure.

25. A method according to any preceding claim, wherein the reductant is a NO_x specific reactant, such as a nitrogen hydride, e.g. ammonia (NH_3) or hydrazine, or an NH_3 precursor.

26. A method according to claim 25, wherein the NH_3 precursor is urea ($CO(NH_2)_2$) or ammonium carbamate (NH_2COONH_4).

27. Apparatus for mapping reductant injection onto NO_x in exhaust gas in a vehicle comprising a lean-burn internal combustion engine and an exhaust system comprising a selective catalytic reduction (SCR) catalyst for reducing NO_x by a desired amount with the reductant, thereby to meet a desired emission standard for NO_x, which apparatus comprising at least one NO_x sensor for measuring NO_x in the exhaust gas, means for measuring at least one measurable parameter indicative of a condition of the engine and means for correlating a measured NO_x value with the value for the at least one measurable parameter.

28. Apparatus according to claim 27, comprising means for using the correlated value to determine the amount of reductant required to reduce the measured value of NO_x to N_2 for the measured value of the at least one measurable parameter.

29. Apparatus according to claim 28, comprising reductant injection means and means for controlling the injection means to inject the amount of reductant so-determined into the exhaust gas.

30. Apparatus according to claim 29, comprising means for measuring exhaust gas downstream of the SCR catalyst for the presence of reductant and NO_x and adjusting the so-determined amount of reductant to reduce NO_x emissions and/or prevent reductant slip as necessary.

31. Apparatus according to any of claims 27 to 30, wherein the correlating means, the reductant amount determining means, the injection controlling means and/or the reductant amount adjusting means comprises a processor.

32. Apparatus according to any of claims 27 to 31, comprising means for storing the correlated values, the amounts of reductant determined and/or the adjusted reductant amounts as a look-up tables or maps.

33. Apparatus according to claim 31 or 32, wherein the processor and/or the storing means is part of the electronic control unit (ECU).

34. Apparatus according to any of claims 27 to 33, wherein the at least one NO_x sensor is positioned upstream and/or downstream of the SCR catalyst.

35. Apparatus according to any of claims 27 to 34, comprising means for detecting reductant in exhaust gas downstream of the SCR catalyst.

36. Apparatus according to any of claims 27 to 35, wherein the SCR catalyst comprises copper exchanged zeolite, such as Cu/ZSM5, or platinum e.g. platinum on alumina.

37. Apparatus according to any of claims 27 to 35, wherein the SCR catalyst comprises supported vanadium such as V_2O_5/TiO_2 or a zeolite, such as mordenite.

38. Apparatus according to any of claims 27 to 37, further comprising a source of reductant.

39. Apparatus according to any of claims 27 to 38, wherein the means for measuring at least one measurable parameter indicative of a condition of the engine measures exhaust gas temperature.

40. Apparatus according to any of claims 27 to 38, wherein the means for measuring at least one measurable parameter indicative of a condition of the engine measures mass flow of exhaust gas in the system.

41. Apparatus according to any of claims 27 to 38, wherein the means for measuring at least one measurable parameter indicative of a condition of the engine measures manifold vacuum.

42. Apparatus according to any of claims 27 to 38, wherein the means for measuring at least one measurable parameter indicative of a condition of the engine measures ignition timing.

43. Apparatus according to any of claims 27 to 38, wherein the means for measuring at least one measurable parameter indicative of a condition of the engine measures engine speed.

44. Apparatus according to any of claims 27 to 38, wherein the means for measuring at least one measurable parameter indicative of a condition of the engine measures throttle position.

45. Apparatus according to any of claims 27 to 38, wherein the means for measuring at least one measurable parameter indicative of a condition of the engine measures the lambda value of the exhaust gas.

46. Apparatus according to any of claims 27 to 38, wherein the means for measuring at least one measurable parameter indicative of a condition of the engine measures the quantity of fuel injected in the engine.

47. Apparatus according to any of claims 27 to 38, wherein the means for measuring at least one measurable parameter indicative of a condition of the engine measures the position of the exhaust gas recirculation (EGR) valve and thereby the amount of EGR.

48. Apparatus according to any of claims 27 to 38, wherein the means for measuring at least one measurable parameter indicative of a condition of the engine measures boost pressure.

49. A vehicle comprising an apparatus according to any of claims 27 to 48.

50. A vehicle according to claim 49, wherein the engine is a diesel engine, such as a heavy-duty diesel engine.

51. A method of mapping reductant injection onto NO_x in exhaust gas in a vehicle comprising a lean-burn internal combustion engine and an exhaust system comprising a selective catalytic reduction catalyst for reducing NO_x to N_2 with the reductant, thereby to meet a desired emission standard for NO_x substantially as described herein.

52. A method of retrofitting a vehicle comprising a lean-burn internal combustion engine with a system for meeting a desired emission standard for NO_x, which system comprising means for injecting a reductant into exhaust gas and a selective catalytic reduction catalyst for reducing NO_x to N_2 with the reductant substantially as described herein.

53. Apparatus for mapping reductant injection onto NO_x in exhaust gas in a vehicle comprising a lean-burn internal combustion engine and an exhaust system comprising a selective catalytic reduction catalyst for reducing NO_x to N_2 with the reductant, thereby to meet a desired emission standard for NO_x substantially as described herein.

54. A vehicle comprising an apparatus according to the invention substantially as described herein.